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PULSE RESPONSIVE DEVICE

Abstract:

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A pulse responsive device, e.g. a pulse rate meter or pulse oximetry device comprises a light emitter (20) and a light sensor (21) for receiving light from the emitter after transmission through or reflection from body tissue, to give an electrical signal varying according to blood flow pulsations. A movement transducer gives an electrical signal representing body movements or vibrations but independent of blood flow pulsations: this transducer may comprise a light emitter (22) and sensor (23) responsive to a different wavelength from the elements (20, 21). The device compares the two electrical signals to cancel out the movement or vibration noise from the signal from the sensor (21).

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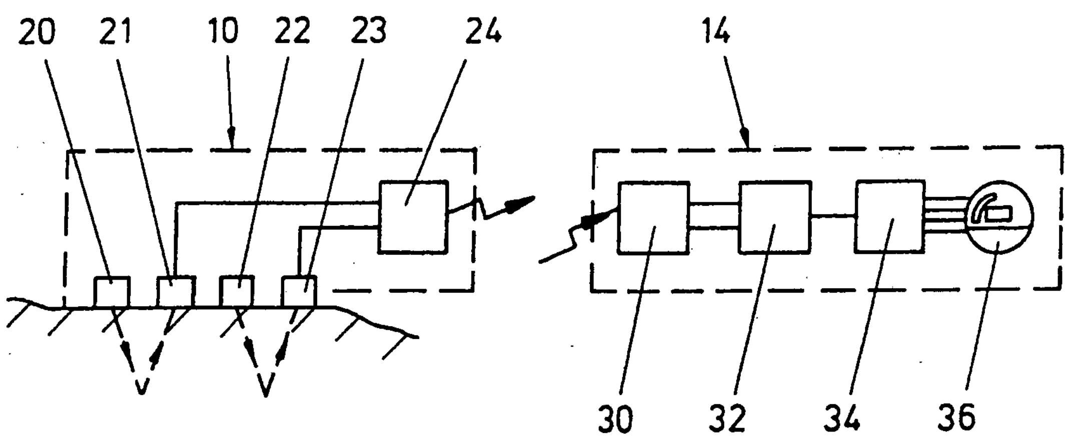

(57) Abstract

A pulse responsive device, e.g. a pulse rate meter or pulse oximetry device comprises a light emitter (20) and a light sensor (21) for receiving light from the emitter after transmission through or reflection from body tissue, to give an electrical signal varying according to blood flow pulsations. A movement transducer gives an electrical signal representing body movements or vibrations but independent of blood flow pulsations: this transducer may comprise a light emitter (22) and sensor (23) responsive to a different wavelength from the elements (20, 21). The device compares the two electrical signals to cancel out the movement or vibration noise from the signal from the sensor (21).

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Pulse Responsive Device

This invention relates to pulse responsive devices and more particularly but not solely to pulse rate meters and pulse oximetry devices.

Pulse oximetry devices, and some other pulse responsive devices, utilise the effect that there is a change in the light transmitted through or reflected from body tissues, due to the pulsing of the blood flow or flow of other body fluid. Such pulse responsive devices include light sensors which produce electrical output signals which can be analyzed to determine various parameters such as pulse rate or blood oxygen saturation for example. Advantages of these devices are that they are non-invasive and they can monitor the relevant parameter on a continuous basis. However, we have found that movements of the body can generate spurious noise in the output signal of the light sensor, thus masking the signal which is to be monitored. We have now devised a device which overcomes this problem.

In accordance with this invention, there is provided a pulse responsive device, having a light emitter, a light sensor for receiving light from the emitter after transmission through or reflection from body tissue and providing an electrical signal having a component varying according to pulsations in blood or other fluid flow through the body tissue, and a transducer responsive to movement or vibration of the body and providing an electrical signal varying according to the body movements or vibrations but independent or relatively independent of the blood or other fluid flow pulsations, and means for comparing one electrical signal with the other.

The electrical signal provided by the light sensor includes, in addition to the component varying according to the pulsations in the blood flow, a noise component due to the body movements or vibrations. Accordingly, by comparing one electrical signal with the other, the noise component due to body movements can be cancelled and an output signal is produced which various with the blood pulsations and independently of the body movements.

The movement transducer may comprise a light sensor

responsive to light transmitted through or reflected from the body tissue, this light being of a wavelength that is unaffected or substantially unaffected by the pulsations in the flow of blood or other body fluids. As an example, we have found that yellow light is suitable for this purpose. However, as an alternative, the movement transducer may comprise a pressure or vibration sensor or an accelerometer. The two electrical signals may be compared by subtracting one from the other to cancel the noise component. Alternatively, the signal from the movement transducer may be analyzed to identify one or more ranges of frequencies corresponding to noise, and the corresponding frequencies are filtered out from the signal from the light sensor. The frequency analysis of each signal may be carried out by fast Fourier Transform techniques.

An adaptive cancellation technique may be used for subtracting the one electrical signal from the other in which cross-correlation is performed between the two electrical signals, and the technique is therefore able to cancel the noise component even if the phase and amplitude relations of the two signals vary with time.

The pulse responsive device in accordance with this invention may comprise a pulse rate meter. This may be adapted for use by joggers. Preferably in this case the light sensor and movement transducer are applied to the forehead. Preferably a read-out device is provided for wearing on the wrist or the back of the hand. Preferably a short wave radio system communicates output signals from the elements on the forehead to the read-out device on the wrist or hand, but instead the read-out unit may be connected to the elements on the forehead by a cable: the read-out unit may be carried in a pocket or clipped onto the user's clothing. In a modification, the read-out device may also be mounted to the head and provide a visual display coupled to the wearer's spectacles. Instead, the entire pulse responsive device may be arranged for wearing on the wrist or the back of the hand.

Also in accordance with this invention, there is provided a pulse rate meter comprising a sensor unit for wearing against the forehead of a user, a read-out device, and a short-wave radio communication system for transmitting an

output signal or output signals from the sensor unit to the read-out device.

Further in accordance with this invention, there is provided a pulse rate meter which keeps cumulative measure of the time that the measured pulse rate has exceeded a predetermined threshold. Preferably this threshold is the lower limit of a training zone, i.e. a range of values between which the user should maintain his or her pulse rate when training. The predetermined threshold may be entered directly into the meter by the user, or may be calculated by the meter from personal data entered by the user, e.g. sex, age, resting pulse rate.

Yet further in accordance with this invention, there is provided a pulse rate meter which has an analogue indicator for displaying measured pulse rate. which is recalibrated upon entering predetermined data. Preferably the analogue indicator includes a "window" corresponding to a training zone and is recalibrated upon entering data which determines this training zone: either the limits of the training zone can be entered directly, or they can be calculated by the meter from personal data entered by the user, e.g. sex, age, resting pulse rate. The resting pulse rate may be measured by the meter when the user is at rest. The lower end of the analogue indicator, upon recalibration, preferably corresponds to the resting pulse rate.

The pulse responsive device may be in the form of a pulse oximetry device. In such case, and in accordance with known principles, two light emitters and two light sensors are provided, operating at two different wavelengths typically 940nm (infrared) and 660 nm (red). The peak-to-peak amplitude variation in each sensor output signal is determined: the ration between the two peak-to-peak amplitudes gives a measure of the blood oxygen saturation level. However, in accordance with this invention, a movement transducer is also provided (of any of the types described above) to give a signal varying with body movements or vibrations but substantially independent of blood pulsations: this signal is compared with the signals from the two light sensors to cancel the body movement or "noise" components from them, before their peak-to-peak

amplitudes are measured and the ratio between those amplitudes is formed.

An embodiment of this invention will now be described by way of example only and with reference to the accompanying drawings, in which:

FIGURE 1 is a view of a jogger wearing a pulse rate meter in accordance with this invention;

FIGURE 2 is a block diagram of the elements of the pulse rate meter; and

FIGURE 3 is a view of the face of the read-out device of the pulse rate meter.

Referring to Figure 1, there is shown a jogger wearing a pulse rate meter in accordance with this invention.

The example of pulse rate meter which is shown comprises a sensor unit 10 attached to a headband 12 so that the sensor unit is applied against the forehead when the headband is being worn. The meter also comprises a read-out device 14 which in the example shown may have a strap for attaching it around the wrist, or it may be attached to a glove-like article so as to be held on the back of the hand. A short-wave radio communication system serves to transmit signals from the sensor unit 10 to the read-out device 14.

Referring to Figure 2, the sensor unit 10 comprises two light emitters 20, 22 and light sensors 21, 23 for receiving light from the respective emitters after reflection within the forehead body tissue. The emitter 20 emits infra red light and the electrical signal provided by the sensor 21 will vary in accordance with the pulsations in the blood flow through the blood vessels in the forehead. The emitter 22 emits light of a different and preferably substantially shorter wavelength, e.g. yellow light, such that the signal from its sensor 23 is relatively independent of variations due to the flow pulsations. Both signals do however vary in accordance with vibrations of the forehead due to movements, and in particular due the feet striking the ground successively as the user jogs. The signals from the two sensors are passed to a short-wave radio transmitter 24 for transmission to the device 14 on the wrist or hand.

The device includes a radio receiver 30 which provides

two signals, corresponding to the output signals of the two sensors 21, 23 to a noise cancellation circuit 32. The latter compares one signal with the other, to give a signal varying as the blood flow pulsations but free of the pedometry vibration or noise: the frequency of variations in the resultant signal is determined to give a measure of pulse rate. The signal from noise cancellation circuit 32 is passed to a processor 34 which drives a read-out display device 36. The noise cancellation circuit 32 may be included in the sensor unit 10 worn on the forehead instead of in the device worn on the wrist or hand, in which case the transmitter 24 transmits the noise-free signal. The noise cancellation circuit 32 may carry out a frequency analysis of the output signals from the respective sensors 21, 23: peaks at corresponding frequencies or frequency ranges in the two signals are regarded as noise and the remaining frequency in the signal from the infra red sensor 21 represents the pulse rate. The frequency analysis of each signal may be carried out by fast Fourier Transform (FFT) techniques. Instead, an adaptive noise cancellation technique may be used, in which cross-correlation is performed between the two electrical signals before one is subtracted from the other, so that the noise component can be cancelled even if the pulse and amplitude relations of the two signals vary with time.

Figure 3 shows the display device 36 of the device 14 worn on the wrist or hand. The device 36 has a digital display 40 normally giving the time, so that the device may be used as a watch. A digital display 41 adjacent the lower end of a scale 45, gives the at-rest pulse rate and a digital display 42 gives the measured pulse rate. Two digital displays 43, 44 give figures defining the lower and upper limits for pulse rate for the individual when jogging, the so-called training zone. An analogue indication of measured pulse rate is also given over the scale 45, which includes a "window" corresponding to the training zone. The device also has a "male or female" indicator 46 and an "age" display 47 both of which can be covered by turning a mask 48.

In use, the device must be preset for the individual user. The "male or female" selection is made by pressing one

of four buttons 49. Successive ages appear on the display 47 by actuation of another one of the buttons until the display shows the age of the user, whereafter the age display remains constant. Then the user puts on the sensor unit 10 and waits for the read-out of measured pulse rate to stabilise. Then another of buttons 49 is pressed, and the pulse rate at that instant (the pulse rate at rest) is thereafter continuously displayed at 41. Alternatively, the device may automatically record and update the at-rest pulse rate each time the actual pulse rate is detected as being lower than that recorded, providing the measured pulse rate is greater than some minimum value (e.g. 40 beats per minute).

From the age, at-rest pulse rate and male or female indication, the processor of the device calculates the training zone, i.e. the lower and upper limits between which the individual concerned should keep his or her pulse rate when training. These limits are displayed in digital terms at 43, 44 and the analogue indicator is correspondingly calibrated.

Then when the wearer is jogging the measured pulse rate is displayed in digital form at 42 and in analogue form at 42 and in analogue form at 45. He or she should aim to maintain the measured pulse rate between the limits of the training zone, i.e. between the values given at 43, 44. This corresponds to keeping the analogue indication within the "window" on the scale 45.

The device keeps a cumulative measure of the time that the measured pulse rate has exceeded the lower limit of the training zone, until this function is reset. The cumulative measure is displayed at 40 instead of the time, by appropriate actuation of the buttons 49. by an alternative actuation of the buttons 49, a stop-watch function is displayed at 40.

Instead of the radio communication link between the sensor unit 10 and the read-out device 14, the read-out device may be connected to the sensor unit by a cable: the read-out device may then be carried in a pocket or clipped onto the user's clothing. Instead, the sensor unit and read-out device may be mounted or combined together and arranged for wearing on the wrist or the back of the hand. In a modification where the sensor unit is worn against the forehead, the read-out

device may also be worn on the head and provide a display visible through the wearer's spectacles.

CLAIMS

1) A pulse responsive device, having a light emitter, a light sensor for receiving light from the emitter after transmission through or reflection from body tissue and providing an electrical signal having a component varying according to pulsations in blood or other fluid flow through the body tissue, and a transducer responsive to movement or vibration of the body and providing an electrical signal varying according to the body movements or vibrations but independent or relatively independent of the blood or other fluid flow pulsations, and means for comparing one electrical signal with the other.

2) A pulse responsive device as claimed in claim 1, in which the movement transducer comprises a light sensor responsive to light transmitted through or reflected from the body tissue and of a wavelength such that its absorption or reflectivity is unaffected or substantially unaffected by pulsations in the blood or other fluid flow.

3) A pulse responsive device as claimed in claim 1, in which the movement transducer comprises a pressure or vibration sensor or an accelerometer.

4) A pulse responsive device as claimed in any preceding claim, comprising means for carrying out a frequency analysis of the two electrical signals and comparing the two analyses to identify said component which varies according to blood or other fluid flow pulsations.

5) A pulse responsive device as claimed in any one of claims 1 to 3, comprising means for carrying out adaptive noise cancellation in comparing the two electrical signals.

6) A pulse responsive device as claimed in any preceding claim, comprising means for applying the light sensor and movement transducer to the forehead of the user.

7) A pulse responsive device as claimed in claim 6 further comprising a read-out device separate from the elements to be worn on the forehead, and a short wave radio system for communicating output signals from the elements on the forehead to the read-out device.

8) A pulse responsive device as claimed in any preceding claim, in the form of a pulse rate meter.

9) A pulse rate meter as claimed in claim 8, arranged to keep a cumulative measure of the time that the measured pulse rate has exceeded a predetermined threshold.

10) A pulse rate meter as claimed in claim 8, comprising an analogue indicator for displaying measured pulse rate, which is recalibrated upon entering predetermined data.

11) A pulse responsive device as claimed in any of claim 1 to 7, in the form of a pulse oximetry device.

12) A pulse rate meter comprising a sensor unit for wearing against the forehead of a user a read-out device, and a short-wave radio communication system for transmitting an output signal or output signals from the sensor unit to the read-out device.

13) A pulse rate meter which keeps a cumulative measure of the time that the measured pulse rate has exceeded a predetermined threshold.

14) A pulse rate meter as claimed in claim 13, in which said predetermined threshold is the lower limit of a training zone.

15) A pulse rate meter as claimed in claim 13 or 14, in which the predetermined threshold is calculated by the meter from personal data entered by the user.

16) A pulse rate meter which has an analogue indicator for

displaying measured pulse rate, which is recalibrated upon entering predetermined data.

17) A pulse rate meter as claimed in claim 16, in which the analogue indicator includes a window corresponding to a training zone and is recalibrated from personal data entered by the user.

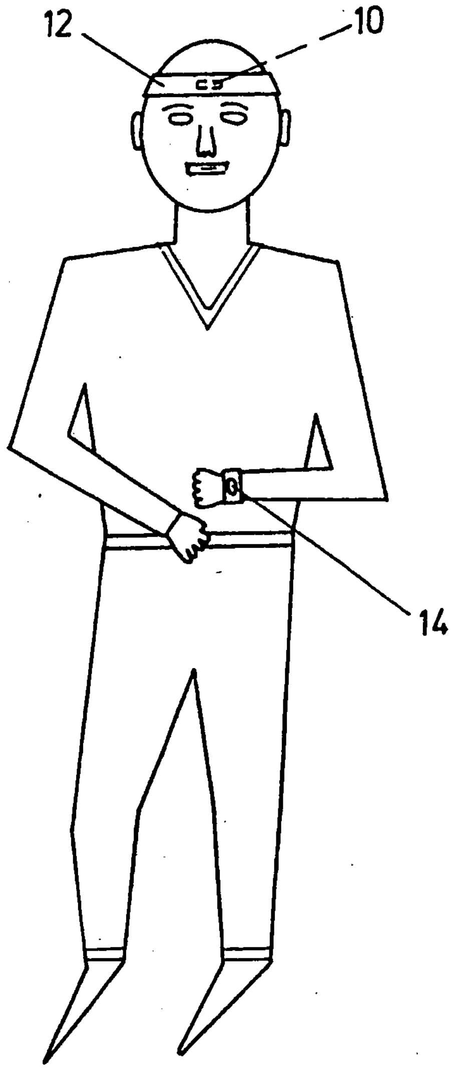

FIG. 1

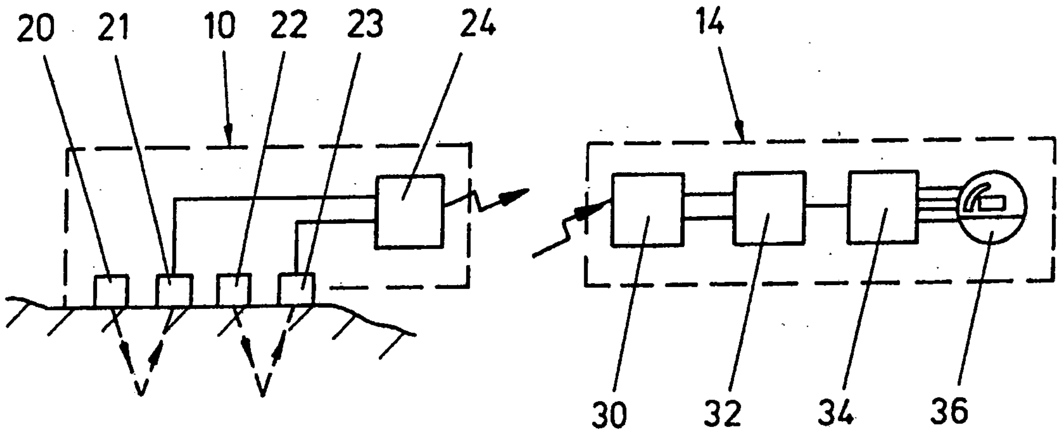

FIG. 2

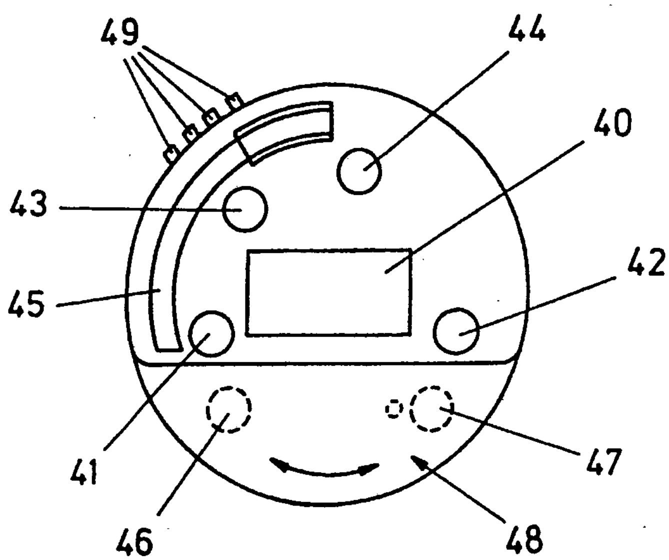

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 91/00841

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 A61B5/024 ; A61B5/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	A61B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	DE,A,3 150 925 (R. WILDEN) June 30, 1983 see page 4, line 4 - page 6, line 32; figures	1,2,4,5, 8
X	US,A,4 409 983 (D.E. ALBERT) October 18, 1983 see column 4, line 62 - column 6, line 24; figures 5-7	1,3-5,8
A	FR,A,2 583 282 (UNIV. DE DIJON & INST. CREUSOT) December 19, 1986 see page 3, line 16 - page 6, line 8; figures see page 8, line 24 - page 9, line 31	1-3,8-10 13-15,17
A	CH,A,669 101 (T. HUBER) February 28, 1989 see page 3, left column, line 31 - page 3, right column, line 44; claim 1; figures	1,2,6-9 11-14

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
25 SEPTEMBER 1991	01 OCT 1991
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	RIEB K.D.

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	DE,A,2 634 050 (B. KÖHLER) February 2, 1978 see page 2, paragraph 5 - page 3, paragraph 3; figures ----	1,3,8-10 13-17

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

GB 9100841
SA 47806

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A-3150925	30-06-83	None	
US-A-4409983	18-10-83	None	
FR-A-2583282	19-12-86	None	
CH-A-669101	28-02-89	None	
DE-A-2634050	02-02-78	None	

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